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A DISTRIBUTED NETWORK ENVIRONMENT FOR INFRARED SENSOR IMAGE ACQUISITION AND SIGNAL PROCESSING

Border Technology

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AFRL-SN-RS-TR-1998-21 has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*

The objectives of this project are to design a distributed network environment for infrared sensor image acquisition and signal processing and implement the design in Rome Laboratory's internal network. The technical problem is to manipulate 12 bit digital infrared image data in an efficient manner that exploits all of the computing power available on the network. The general methodology is to maintain the network operating systems at the release levels that will optimize the computational throughput of the network, and to arrange the data so that it is logically close to the user and network node that will perform the mathematical operations. The proximate location of the data and the compute engine reduces the effect of network bandwidth limitations inherent in conventional Ethernet networks. This arrangement of data will improve the effective performance of the individual nodes on the network.

The network improvements implemented under Contract F19628-93-C-0058 was specific to the existing network configuration at Rome Laboratory. New equipment was added to the existing network to make it specific to IR image processing algorithm development. It is our belief that the configuration proposed and established for Rome Laboratory is of no use to other researchers, because it is particular to the algorithm development and the pre-existing network at Rome Laboratory. Additionally, computer technology is changing so rapidly that it would be advantageous for other researchers to use the newest and best equipment and not to base their network on the network implemented at Rome Laboratory.

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Technical Objectives:

The Objectives of this project are to design a distributed network environment for infrared sensor image acquisition and signal processing and implement the design in Rome Laboratory's internal network. The technical problem is to manipulate 12 bit digital infrared image data in an efficient manner that exploits all of the computing power available on the network. The General methodology is to maintain the network operating systems at the release levels that will optimize the computational throughput of the network, and to arrange the data so that it is logically close to the user and network node that will perform the mathematical operations. The proximate location of the data and the compute engine reduces the effect of network bandwidth limitations inherent in conventional Ethernet networks. This arrangement of data will improve the effective performance of the individual nodes on the network.

Report Summary and Technical Results:

The implementation of a distributed network environment for infrared sensor image acquisition and signal processing was performed in three phases. First, the available network resources were upgraded, second the data acquisition process was improved and third, the network was reconfigured to reduce data flow bottlenecks. This report will detail the process by which the three phases were implemented and summarize the current configuration of network resources.

The first phase of the program was to perform a thorough evaluation of the current workstation capabilities and to determine if the hardware is suitable for processing the data from the next generation of infrared cameras. In this environment, it is crucial to evaluate the workstation products of the major manufacturers not only in terms of which company has the lead in price/performance today, but which computing systems have the most potential for growth when specifically considering image processing of infrared data.

While it is tempting to form the network by including hardware from all of the major manufacturers, thereby taking advantage of each of their strengths, this approach presents a software nightmare. Separate versions of all source code and executable binary code must be stored and made available to users, in a heterogeneous computing environment. In addition to multiplying the required disk space by several factors, such a network would surely have a higher system traffic and would require

many times the development and maintenance effort to resolve source code incompatibilities between platforms.

The open architecture of the SparcStations makes them ideal for data acquisition from either high speed digital tape recorders, or custom camera frame buffers, consequently, it was determined that a homogeneous SUN workstation environment would be most efficient. In addition, we decided to upgrade all the workstations in the network to the latest stable version of the operating system, SUNOS 4.1.3. This permitted the use of some of the slower workstations as diskless nodes that functioned as display servers. In general, it is found that 90% of the computing work on the network is performed by the top three fastest workstations.

During this period, several hard disk failures occurred which required hardware replacement, an 8mm streaming tape drive with a 5 GB formatted capacity was installed, several Sbus frame buffer boards were installed, and work was begun on the Sbus implementation of the DR11W I/O interface which was currently functioning on one of the slower workstations.

In addition a *yellow pages* database was created with all the user information. The database would permit quick reconfiguration of network resources in the event of a workstation crash or network reorganization. The users home directories were centralized onto three servers for simpler administration and backup. The 8mm tape drive was configured to backup all user files from these servers every night at 1:15 AM. A minimum of one month of backups is maintained which enables users to recover lost files provided they discover the loss within 30 days.

The second phase of the program targeted the data acquisition requirements of Rome Laboratory, but continued to modify network resource as needed. The data acquisition capabilities of the current workstations were studied and optimized to capture infrared data. Clearly there is no best approach to capture data from an infrared camera; different types of measurements have different data acquisition requirements. Nevertheless, the chosen data acquisition mechanisms can accommodate virtually all of the measurement requirements.

Three major data acquisition items were completed during this phase of the program. First, a faster, more compact and more reliable Sbus version of the VME based DR11W I/O board, called the S11W was installed in a SparcStation 10/30. This board and workstation combination reduced the frame transfer time from the camera to the network by several orders of magnitude. The transfer time required for a 320 x 244 camera operating at 30 frames per second is approximately 0.25 s.

The second data acquisition item that was completed was the selection and purchase of a SPARC based laptop computer for use in mobile frame acquisition., and the reconfiguration of an additional SPARC based laptop for archiving acquired data frames to an 8mm tape. The laptop that initially arrived from the manufacturer was not functional due to a memory parity error which created random load errors during the installation of the operating system. The fault was diagnosed and sent back to the manufacturer for repair. The repaired laptop was configured as the SparcStation 10/30 for frame acquisition using the S11W I/O board.

The third data acquisition item that was completed was the evaluation and purchase of portable hard disk drives. Three 2.4 GB hard disks were installed on the network. Performance benchmarks indicated that each hard drive will hold 450 seconds of data from a 320 x 244 camera operating at 30 frames per second. The peak transfer rates for these hard disks is 10 MB/sec, and the sustained transfer rate for these hard disks is 1.9 MB/sec.

The SparcStation 10/30, and both of the laptops were configured to automatically sense and mount whichever of the three hard disk drives were attached. In addition a backup mechanism was implemented which permitted all of the data in each of the hard disks to be backed up to an 8mm tape with a single command. These modifications were performed for a joint Israel and USA data acquisition measurement program.

The latest trends in workstation networking indicate that UNIX Vr4 will be the future operating system standard. Currently the RL network is using SUNOS UNIX based on BSD4.3. Migration of Rome Laboratory's network to the UNIX Vr4 standard will increase their real time data acquisition capabilities, but will also improve their network performance. UNIX Vr4 will have a more robust Network File System (NFS), automounter, and Network Information Service (NIS). In addition, NFS data throughput is expected to improve by moving to streams from socket based Remote Procedure Calls (RPC). The newest version of UNIX Vr4 from Sun Microsystems is expected to be capable of fully symmetric multiprocessing and multithreading. These are tremendous advantages to signal processing problems on arrays of data which can be easily vectorized.

During this phase several improvements and modifications to the network were implemented, including the evaluation of the Solaris 2.1, 2.2, and 2.3 versions of the operating system which is based on UNIX Vr4. Only the Solaris 2.3 version of the operating system was found to be stable enough for limited use. The Solaris 2.X versions of the operating system are attractive alternatives to SUNOS because the support multi-processor based workstations.

In addition to operating system changes, a C compiler for Solaris 2.3 was installed on the network, a 128 gray level printer/plotter was installed for image display, and a SparcStation 10/512 and SparcStation 10/40 was installed on the network, and an additional 8mm tape drive was installed for the Israel measurements. The SparcStation 10/512 is a two CPU workstation with 1MB of secondary static RAM cache for each processor. Several additional frame acquisition hardware tools were also installed on the network during this time.

The third phase of the program attempted to reconfigure the network to reduce data flow bottlenecks. Achieving the necessary performance from these workstations depends on balancing network performance with individual computer system performance. For example, the speed with which a workstation can capture an image is important, but if the image is to be displayed remotely, across an Ethernet connection, the ability to display a sequence of frames to form a video may be limited by the network bandwidth.

The network architecture which links the various workstations was evaluated and reconfigured to maximize data throughput. Without considering alternatives to the Ethernet standard, an improvement in network performance was achieved with a study of the data paths throughout the network, and a subsequent targeting of the data flow bottlenecks which were identified. Specifically, the location of data archives, data acquisition, user files, image processing computation, and processed image display were reorganized to eliminate bottlenecks in the data flow.

The network model developed to optimize the data flow is consistent with the three file server approach implemented in the first phase of this program if the file servers are also acting as compute servers. This model is not consistent with typical client/server implementations.

Typically a client/server application is structured to emphasize data services on the server and compute services on the client. The intent in client/server applications is to take advantage of many low cost processors available on the clients to distribute the compute load, while maintaining the data integrity and administration functionality of the a mainframe (with reduced compute requirements), on the server.

This approach works well when the data sets are small, and the compute requirements on the data can be easily partitioned into independent tasks. The infrared image processing problem deals with data sets that are huge and compute requirements that can be partitioned into dependent tasks. We have converged on a model which

reduces the importance of network bandwidth by combining the image processing compute services and the data services onto the server and off-loading the display compute services onto the client.

This model has room to grow with the application of multiprocessor based computing to the server.

Cost Elements:

Labor Category	Cumulative Hours
Principal Investigator	1252
Administration	307

The following data is taken from forms SF-1034 and SF-1035 dated 1-May-1995.

Major Cost Elements	Amount for Current period Billed	Cumulative Amount from inception to Date of this Bill
Direct Labor	$0.00	$50,080.00
Labor Overhead	$0.00	$17,455.00
Direct Materials	$0.00	$862.00
Direct Costs	$0.00	$6,272.00
Indirect Costs	$0.00	$5,189.00
G & A	$0.00	$5,589.00
Total Costs	$0.00	$85,447.00
Fee	$778.65	$5,193.00
Total Amount Claimed	$778.65	$90,640.00

Adjusted Amounts Claimed

Current and Cumulative Costs	$0.00	$85,447.00
Fee	$778.65	$5,193.00
Total	$778.65	$90,640.00